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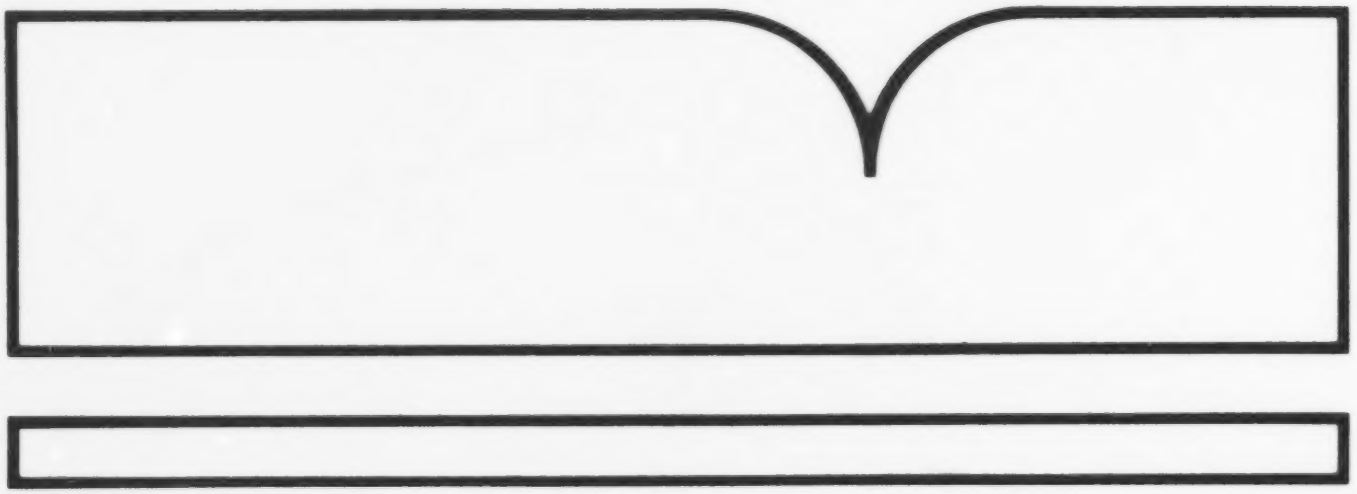
Operating Experience with EPA's (Environmental Protection Agency's) Mobile Incineration System

Enviresponse, Inc., Livingston, NJ

Prepared for

Environmental Protection Agency, Cincinnati, OH

Feb 88



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Frank J. Freestone, Project Officer — FTS 340-6632 (201) 321-6632

16. ABSTRACT

This paper describes the recent modifications made to the U.S. Environmental Protection Agency's (EPA) Mobile Incineration System. These modifications were aimed toward increasing the capacity of the system as well as its on-stream factor.

The operation of the modified system was resumed on June 1, 1987. During the three month period following that, various system performance tests were conducted. Besides these tests, over a million pounds of dioxin-contaminated solids and liquids including soil, plastics, trash, grass, tyvek, clothing, wood, etc. have been incinerated. A brief summary of the various test results and the highlights of the major problems encountered during the system operation, adopted solutions, and lessons learned are also presented in the paper.

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By

Gopal D. Gupta and R. Sawyer
Enviresponse Incorporated
110 South Orange Avenue
Livingston, NJ 07039

Frank J. Freestone
U.S. Environmental Protection Agency
Hazardous Waste Engineering Research Laboratory
Releases Control Branch (Edison, NJ 08837)
Cincinnati, OH 45268

and

R. Hazel
U.S. Environmental Protection Agency
726 Minnesota Avenue
Kansas City, Kansas 66101

EPA Contract 68-03-3255

EPA Project Officer
Frank Freestone

HAZARDOUS WASTE ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OH 45268

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OPERATING EXPERIENCES WITH EPA'S MOBILE INCINERATION SYSTEM

Gopal D. Gupta and R. Sawyer
Enviresponse, Inc.
110 South Orange Avenue
Livingston, NJ 07039

F. Freestone
U.S. Environmental Protection Agency
Hazardous Waste Engineering Research Laboratory
Releases Control Branch (Edison, NJ 08837
Cincinnati, OH 45268

and

R. Hazel
Region 7
U.S. Environmental Protection Agency
726 Minnesota Avenue
Kansas City, Kansas 66101

ABSTRACT

This paper describes the recent modifications made to the U.S. Environmental Protection Agency's (EPA) mobile incineration system. These modifications were made to increase the capacity of the system and to improve its on-stream factor.

The operation of the modified system began on June 1, 1987. During the following three month period various system performance tests were conducted. Additionally, over a million pounds of dioxin-contaminated solids and liquids including soil, plastics, trash, grass, Tyvek^{R} clothing, wood etc. have been incinerated. A brief summary of the various test results, the highlights of the major problems encountered during the system operation, adopted solutions, and lessons learned are presented.

The information presented will be of interest to those considering operation of mobile or transportable incineration systems under field conditions for the purpose of cleanup of Superfund or other hazardous waste sites.

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INTRODUCTION

The objective of this paper is to describe the recent modifications made to the EPA's mobile incineration system (MIS) and to present operating experiences with the modified system.

The MIS was originally designed and constructed to demonstrate the high-temperature incineration of toxic and hazardous wastes (1). The system essentially consists of a refractory-lined rotary kiln, a secondary combustion chamber (SCC), and an air pollution control system mounted on three heavy-duty semi-trailers. Monitoring equipment is carried by a fourth trailer.

The MIS was rigorously tested in Edison, N.J. during 1982-83 with PCB-contaminated liquids and other chlorinated organic fluids (2). After completing these tests successfully, the system was modified to enable incineration of solid wastes in a field demonstration. The MIS was transported to the Denney Farm site in McDowell, Missouri in December 1984 for a trial burn on dioxin-contaminated solids and liquids and subsequent field demonstration. The details of the dioxin trial burn conducted at the Denney Farm site have been presented in an EPA report available from the National Technical Information Service (3). A variety of dioxin-contaminated materials was incinerated by the MIS between July 1985 and February 1986. By February 1986, over two million pounds of solids and approximately 180,000 lb of liquids had been incinerated during a total of 170 operating days.

The operating experience during the 1985-86 period demonstrated the capacity of the MIS to be 2,000 lb/hr for soil with relatively low moisture content and low heating value. Since the MIS was a prototype system, the on-stream factor was modest (45-55%) during this operation. Two primary causes identified for this on-stream factor were:

- Excessive particulate carryover from the kiln which accumulated in the SCC.

- Extensive maintenance required on the irrigated fiberglass mat type particulate gas filter.

A detailed discussion of the lessons learned and of the problems encountered during the 1985-86 system operation is provided in reference (3).

In February 1986, the system was shutdown for approximately one year. During this shutdown period, a design study was undertaken in order to increase the MIS capacity and increase its on-stream factor. A brief summary of this design study is presented herein. Various system modifications implemented on the MIS as a result of the design study are discussed. The

operational experience with the modified system is presented next. The operational experience relates to the period between June 1 through September 14, 1987 and includes a brief summary of various performance tests conducted on the system as well as a highlight of the major problems encountered during this operation. A trial burn was conducted in July and August, 1987, however, data from those tests has not, at the time of this writing, been fully evaluated and will be presented in a later paper.

SYSTEM MODIFICATIONS

As mentioned earlier, during the 1985-86 operation, the MIS had shown that only 2,000 lb/hr of soil with relatively low moisture content and low heating value could be incinerated. Higher moisture content or higher heating value feeds further reduced the system capacity. Also, a modest on-stream factor (45-55%) was experienced during this operation. Since the economics of the MIS are directly dependent on the system capacity and its on-stream factor, a design study was undertaken to determine the capacity-limiting factors and the primary causes of the system unavailability.

Capacity:

It was found that the capacity limitation of the MIS resulted primarily from:

- Volume of the ram feed trough which determined amount of material charged.

- Flue gas volumetric flow rate through SCC which approached the required minimum 2 second gas residence time.

The first limitation was easily eliminated by increasing the volume of the ram feed trough from 0.5 ft^3 to 1.2 ft^3. With the ram stroke frequency ranging from 1 to 1.5 strokes per minute, the feed system now has a maximum capacity of 108 ft^3/hr. For a soil with density of approximately 70 lb/ft^3 and the normally used ram stroke rate at 1 stroke per minute, the feed system can push approximately 5,000 lb/hr of soil into the kiln.

In order to overcome the second limitation, the conventional air burners in the kiln were replaced by an oxygen-enrichment type burner system. The Linde® "A" Burner System* (from Union Carbide) was selected as a replacement for one of the two existing air burners. The "A" burner uses 100% oxygen and, thereby partially eliminates the nitrogen portion of the combustion air required for incineration. In the MIS, the SCC still uses conventional air burners. Use of oxygen instead of air reduces the volume of nitrogen and flue gas in the system

and increases the concentration of oxygen in the fuel-oxidant mixture. The major advantage of this modification is that the system throughput is easily doubled while maintaining SCC residence time above the two second regulatory limit.

A schematic of the "A" Burner is shown in Figure 1 (4). More details about the "A" Burner can be found in references (5-6). A unique feature of this burner is that it produces a flame having a temperature measured by Linde as being no greater than the conventional air burner flame temperature. This is accomplished by aspirating the furnace gases into the oxidant jets prior to mixing with the fuel as shown in Figure 1 by the small arrows. The distance between the oxygen jets and fuel supply is adjusted such that a sufficient amount of furnace gases are aspirated into the oxygen jet to reduce the flame temperature. The resulting flame temperature is equivalent to that produced by a conventional air burner.

Based on a computerized simulation of the kiln conditions of the MIS, the fuel requirement and flue gas volume are plotted with respect to the system throughput in Figure 2 for the previous air system and for the oxygen system (modified MIS). Soil with 20% moisture and the same level of oxygen concentration in the flue gas was considered for both cases . Figure 2 clearly shows that the 2 second residence time limit cannot only be met at feed rates above 2,000 lb/hr using the air system. However, a throughput of even 6,000 lb/hr using the oxygen system amply meets this requirement. Figure 2 also shows that over 50% savings in the combustion fuel requirement is theoretically achieved by the use of oxygen.

On-line Factor:

An analysis of the system operations on clay soils during the 1985-86 period revealed that the two primary causes of downtime were:

- Excessive particulate carryover from the kiln which accumulated in the SCC and necessitated system shutdowns for cleanout approximately every week.

- Extensive maintenance required on the irrigated fiberglass mat type particulate gas filter.

In order to mitigate these problems, the following system modifications were implemented:

- o A refactory lined cyclone was installed between the kiln and the SCC.

- o The gas filter was replaced by a wet electrostatic precipitator (WEP).

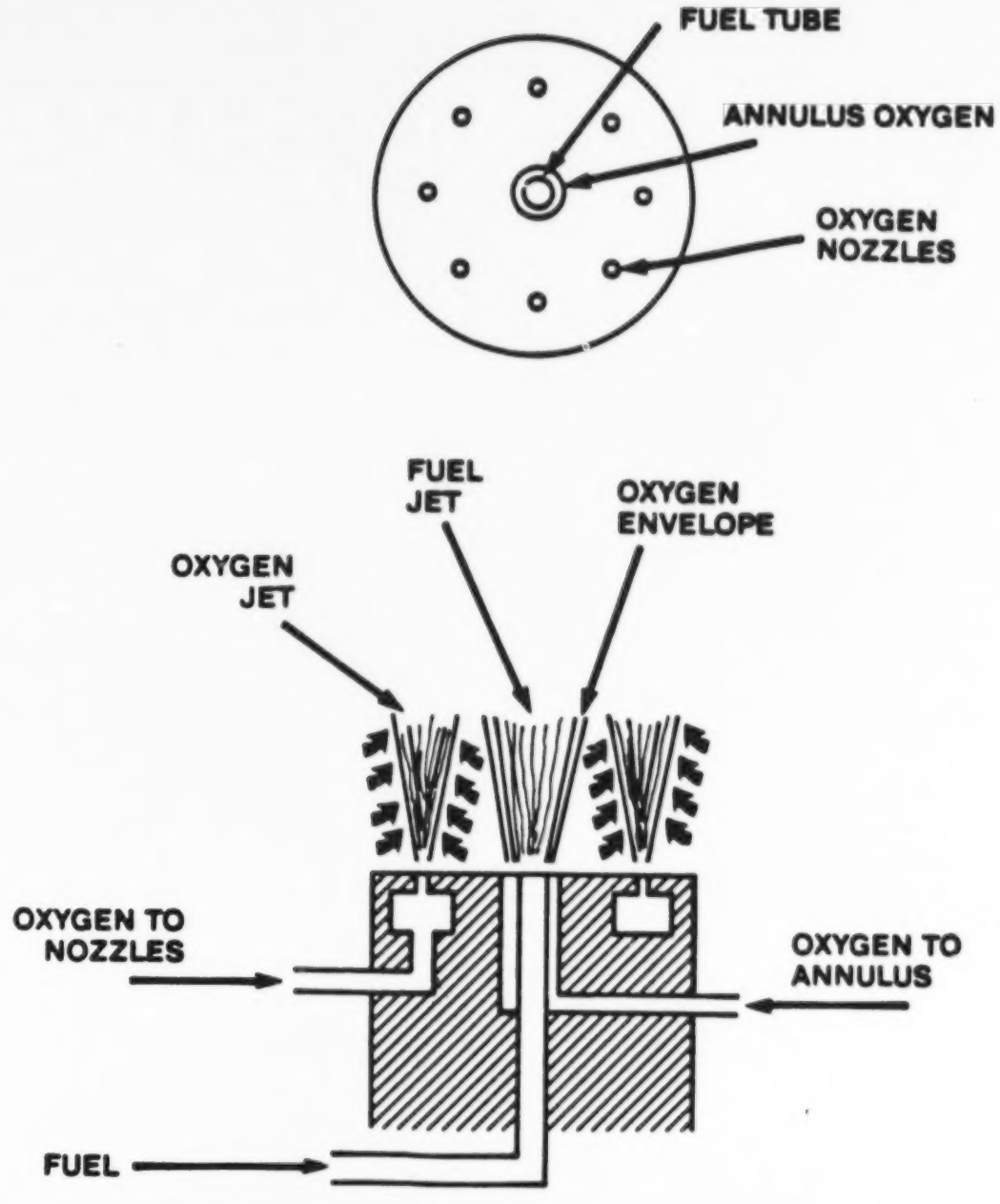

FIGURE 1.
SCHEMATIC SKETCH OF THE A-BURNER

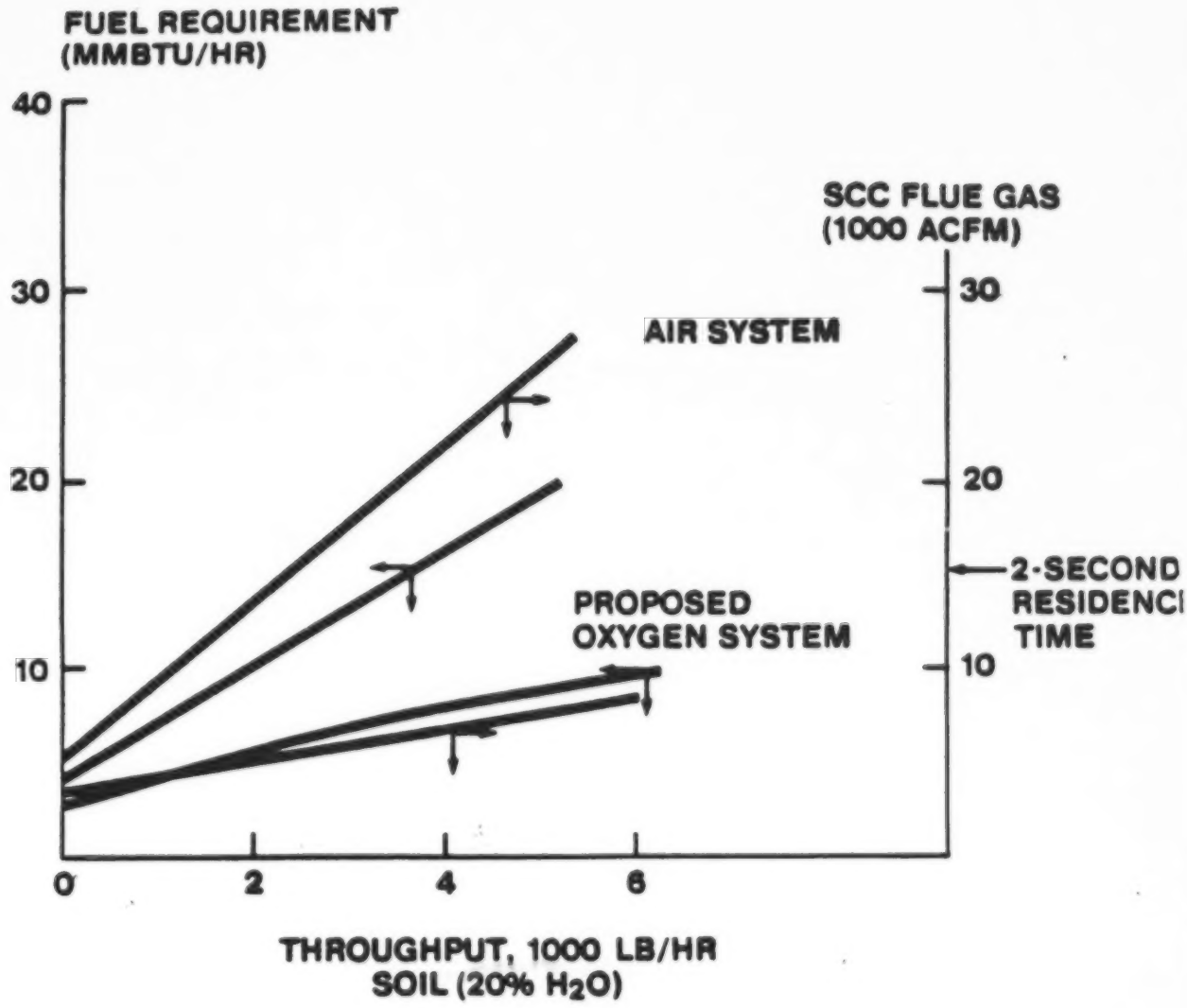

FIGURE 2.
CALCULATED FUEL REQUIREMENT AND FLUE GAS VOLUME FOR
THE EPA MIS VS. THROUGHPUT

Additionally, the oxygen burner was expected to produce a kiln gas velocity only 1/3 of the previous minimum gas velocity, resulting in less particulate carryover from the kiln into the downstream equipment.

During the 1985-86 operation, samples of the material accumulated in the SCC and from the quench water cleanup system (hydroclones) were taken. Particle size analyses on these samples showed that the mean particle size of the SCC material ranged from 57 to 128 microns (depending upon the feed) whereas the mean particle size of the hydroclone material was 23 microns. Utilizing this information, the cyclone was designed to remove 90% of the total particles and 93% of particles larger than 20 microns. Most of the smaller particles entering the SCC were expected to be entrained in the flue gases and captured in the wet electrostatic precipitator. The goal of these modifications was to increase the MIS capacity by a factor of two and increase its on-stream factor to 80%, thereby increasing the overall throughput by more than a factor of three. The actual performance of the modified system will be discussed in the following sections of this paper.

SYSTEM PERFORMANCE RESULTS

After the system modifications were completed, the MIS operations were resumed on June 1, 1987. The burners were ignited on June 1 and the solids were first fed to the system on June 10, 1987. During the following 14 weeks of system operation, over a million pounds of dioxin-contaminated solids and liquids were incinerated. In addition, several tests were conducted in order to determine the performance limits of the system. A trial burn and associated tests were also conducted to attain the appropriate Resource Conservation and Recovery Act (RCRA) and Toxic Substances Control Act (TSCA) permits in preparation for potential future projects. The objectives of these tests included:

- Determine the soil feed rate limit of the modified system on clean soil.
- Verify by stack particulate data and analysis of kiln ash, cyclone ash, sludge and process water that the MIS as modified was still achieving adequate performance on dioxin-contaminated soils at the new feed rate.
- Determine the maximum amount of chlorine that can be fed to the system (in solid and liquid feeds together).
- Ascertain the feed rate limit on vermiculite (very low density feed) and brominated industrial sludge in preparation for future projects.

- Establish system stability (combustion and flame pattern) with soil mixed with diesel oil to simulate high BTU soils.

- Determine the stack particulate emissions from high-chlorine feeds; (200 lb/h equivalent chlorine) vermiculite at 600 lb/hr; and brominated sludge (mixed with soil and sodium sulfate) at 4,000 lb/hr.

- Perform a trial burn simultaneously with RCRA-regulated solids [hexachloroethane (HCE)] and liquids [carbon tetrachloride (CCl_4)] and TSCA-regulated polychlorinated biphenyls (PCBs-solids and liquids).

Verification Tests

After the modified system resumed operations, the MIS was required to demonstrate successful particulate emission results at 4,000 lb/hr before normal operations could be continued at this rate. In addition, to confirm their previous non hazardous status, delisting analyses were also required on the four effluent streams namely: kiln ash, cyclone ash, sludge and the process water. A list of delisting parameters and their regulatory limits are shown in Table 1. Only organic compounds are listed in this table. Analyses were also required for various metals in the effluent streams.

The stack particulates during these tests were 0.04 gr/dscf, well below the regulatory limit of 0.08 gr/dscf. All effluent streams (ash solids and scrubber liquid) also met the delisting requirements. Thus, as a result of these tests, the MIS was permitted to operate at 4,000 lb/hr of dioxin-contaminated solids. All effluents were delisted, and hence, could be discharged as non-hazardous wastes.

Feed Rate Tests

It is well known that feed rate limits for a specific incineration system operating at given operating conditions depend upon the feed characteristics. The MIS SCC operating conditions are within those specified by the PCB regulatory requirements. They are also consistent with those previously demonstrated during the dioxin trial burn. For example, the SCC is operated between 2050-2200^{o}F with a gas residence time of at least two seconds, etc. Various feed characteristics parameters that affect the feed rate are given in Table 2.

A wide variety of feeds were processed by the mobile incinerator during the testing period. A summary of various feed rate test results is presented in Table 3. With normal, relatively dry (less than 20% moisture) soil, it was quite easy to feed up to 5,000 lb/hr. During the hot summer months,

TABLE 1 - DELISTING PARAMETERS AND LIMITS
1987 OPERATIONS

Substance	Ash Solids	Scrubber Waste Liquids
Chlorinated dibenzodioxins/furans	1 ppb	10 ppt
2,3,4-Trichlorophenol	1.0 ppm	50 ppb
2,4,6-Trichlorophenol	17,000 ppm	55 ppm
2,5-Dichlorophenol	0.2 ppm	10 ppb
3,4-Dichlorophenol	0.2 ppm	10 ppb
2,3,4,5-Tetrachlorophenol	1.0 ppm	50 ppb
2,3,4,6-Tetrachlorophenol	636 ppm	5 ppm
1,2,4,5-Tetrachlorobenzene	64 ppm	0.2 ppm
1,2,3,5-Tetrachlorobenzene	1.0 ppm	50 ppb
Hexachlorophene	10 ppm	500 ppb
PCBs	0.3 ppm	0.1 ppb
PNAs		
Benz(a)pyrene	0.038 ppm	19 ppt
Benz(a)anthracene	0.097 ppm	0.1 ppb
Chrysene	15 ppm	3 ppb
Dibenz(a,h)anthracene	0.007 ppm	11 ppt
Indeno(1,2,3,-cd)pyrene	29 ppm	3 ppb
Benz(b)fluoranthene	0.16 ppm	0.3 ppb
Tetrachloromethane	0.17 ppm	5 ppb
Hexachloroethane	67 ppm	0.4 ppm

TABLE 2 - FACTORS AFFECTING FEED RATES

CHLORINE CONTENT	NEUTRALIZATION CONTROL
DENSITY	RAM FEED VOLUMETRIC LIMIT
BTU CONTENT	KILN HEAT RELEASE LIMIT 8 MM BTU/HR TEMPERATURE CONTROL
ORGANIC CONCENTRATION	ASH DELISTING LIMITS
SLAGGING TENDENCY	BUILDUP OF SLAG IN KILN
MOISTURE CONTENT	FEED SYSTEM DESIGN SCC GAS RESIDENCE TIME
STEEL CONTENT	SHREDDER CAPABILITY

TABLE 3 - FEED RATE TESTS

FEED	RATE (LB/HR)	CONTROLLING FACTOR
CLEAN SOIL	5,300	CORBEL
DIOXIN SOILS (NORMAL OPERATIONS)	4,000	FEED CREW HEAT STRESS
CCL_4 LIQUID	200 (CL)	NOT AT LIMIT
TRIAL BURN MIX (LIQUIDS & SOLID)	250 (CL)	QUENCH SUMP INSTABILITY (PH CONTROL)
SOIL WITH DIESEL FUEL (HI BTU SOIL)	4,000 (330 BTU/LB)	NOT AT LIMIT
VERMICULITE (4 LB/CU FT)	600	RAM FEED VOLUMETRIC LIMIT
MUD (WET SOIL)	2,000-3,000	MOISTURE CONTENT FEED SYSTEM
MUD + PLASTIC	1,000-2,000	MOISTURE, FEED SYSTEM, KILN SLAGGING
VERMICULITE + SOIL	200+1400 = 1600	RAM FEED VOLUMETRIC LIMIT
TRASH ONLY	200-700	RAM FEED & KILN SLAGGING
50% TRASH, 50% SOIL (vol)	1,000-1,200	RAM FEED & KILN SLAGGING
27% SLUDGE, 1% SALT CAKE, 72% SOIL (wt)	4,000	ASH QUALITY
42% SLUDGE, 1% SALTCAKE, 57% SOIL (wt)	2,900-3,900	ASH QUALITY
METAL DRUMS OPERATIONS	4 drums per hour	SHREDDER: 12/HR

however, the primary limiting factor to sustaining a constant feed rate of over 3,000 lb/hr was the heat stress of the feed crew (outfitted in protective clothing and respiratory protection). The quench system was the limiting element for high chlorine feeds. No more than 200 lb/hr of chlorine in feed materials could be fed without causing automatic system shutdowns due to a high degree of effervescence in the quench sump (resulting in quench pump cavitation and quench interruption).

Tests were also performed on vermiculite and two brominated waste mixes containing different fractions of brominated sludge, soil, and sodium sulfate salt cake. A feed rate of 4000 lb/hr was demonstrated for a mixture containing 27% sludge and a feed rate of 3000 lb/hr was demonstrated for a mixture containing 42% sludge. Both wastes contained only 1% of salt cake. Up to 800 lb/hr of the very low density vermiculite (4 lb/ft^3) was successfully processed.

Other feeds had limited feed rates as follows:

- Wet soil mixed with plastics: Only 1000 to 2000 lb/hr of this mixture could be processed. There were significant quantities of this wet soil which was brought in by truck. Large amounts of plastics came from the liners which protected the trucks from contamination with dioxin. Also, moderate kiln slagging reduced equipment availability with this material.

- Trash: Feed rates of 200 to 700 lb/hr were feasible as limited by kiln slagging. This material consists of plastic clothing, rubber gloves, and boots, wooden pallets, glass, paper, insulation, etc.

- Metal drums: The system was able to process 10 to 12 drums per hour. Since other feed can be processed simultaneously, drums do not limit total feed rate.

Particulate Tests

In preparation for the planned RCRA/TSCA trial burn, particulate tests were also conducted with simultaneous feeding of 4,000 lb/hr of soil and 200 lb/hr of CCl_4. The results clearly showed that particulate emissions depended directly on the amount of chlorine fed to the system as shown in Figure 3. A number of simple system changes were tried without any success. The high particulate emissions were traced to the fact that a large amount of mist with dissolved sodium chloride was entrained in the stack gas. The sodium chloride showed up with the particulates on the test filters. The problem was solved by installing a mist eliminator in the last stages of the MX scrubber. High chlorine feed tests were extremely successful after demister installation.

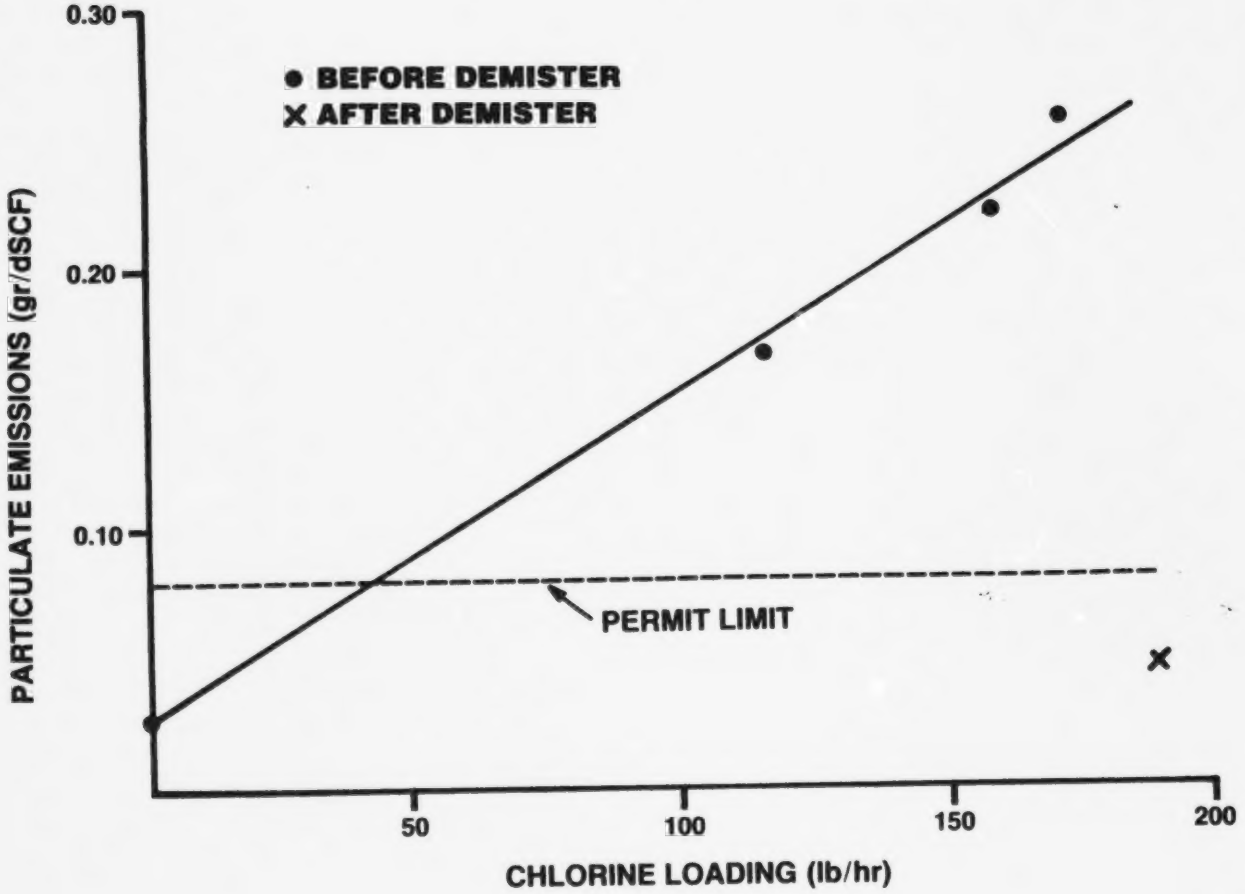

FIGURE 3.
EFFECT OF CHLORINE LOADING ON PARTICULATE EMISSIONS

It was hypothesized that the total dissolved solids (TDS) in the process water had a significant effect on the stack particulates. Therefore, a particulate test was conducted with no feed to the system, high TDS in process water and approximately the same flue gas flow rate as in the other tests. The test showed a particulate emission of 0.02 gr/dscf with the process water TDS of approximately 50,000 parts per million (ppm) confirming the hypothesis.

The particulate tests with vermiculite and the two mixes of brominated sludge, soil and salt cake were also successful. These results are summarized in Table 4.

System Stability Tests

A number of system stability tests were conducted with various feeds in preparation for the planned trial burn tests. The following tests were performed:

- Liquid waste feed tests: Liquid waste was fed up to 2.7 MMBtu/hr (MM=1,000,000) at a steady rate and was cycled between 0 and 2.2 MMBtu/hr.

- Water spray cycling: Water spray was cycled at rates between 0 and 2.5 gpm.

- Methanol/water feed: A mixture of 80% methanol and 20% water (7,000 Btu/lb) was fed up to 2.1 MMBtu/hr.

- Methanol/CCl_4 feed: A mixture of 77% methanol and 23% CCl_4 (7,500 Btu/lb) was fed up to 3 MMBtu/hr.

- Diesel/CCl_4 feed: A mixture of 62% CCl_4 and 38% diesel (7,500 Btu/lb) was fed up to 3 MMBtu/hr.

- High Btu soil feed: 4,000 lb/hr. of soil/diesel mixture with heating value of 330 Btu/lb was fed simultaneously with liquid fuel at 2.2 MMBtu/hr. Total heat input from waste was 3.5 MMBtu/hr.

Satisfactory system response and flame stability were demonstrated in all the above tests.

RCRA/TSCA Trial Burn

A combined RCRA/TSCA trial burn was conducted in which PCB and HCE were fed with 4,000 lb/hr of soil and liquid PCB and CCl_4 in 315 lb/hr of liquid feed. Four tests were completed. Only solids were fed in the first test. A trial burn report detailing the results of these trial burns will be issued.

TABLE 4 - STACK PARTICULATE EMISSION TESTS

FEED	RATE (lb/hr)	PARTICULATES (gr/dscf)*
Clay soils	4,000	0.04
Soils + CCL4	4,000 + 200	0.26 (over limit of .08)
Soils + CCL4	4,000 + 200	0.05 (with demister)
27% Sludge 1% Salt 72% Soil (wt)	4,000	0.07
42% Sludge 1% Salt 57% Soil (wt)	3,500	0.08
Blank (50,000 ppm TDS in H_2O)	No Feed	0.02
Vermiculite	600-700	0.02

* corrected to 12% CO_2

PROBLEMS, SOLUTIONS AND LESSONS LEARNED

During the 14-week operation of the modified system, a number of problems were encountered. An overall system availability of 53% was achieved. The factors that account for the 47% unavailability and their proportion are presented in Tables 5 and 6. Table 5 shows that out of 47%, about 7% was due to delays related to testing. The next major cause of the unavailability was the feed characteristics. Both kiln slagging and feed system jamming were a direct result of the excessive plastic, rubber and other trash in the wastes materials. The unavailability due to maintenance primarily represents the downtime during the demister installation. Thus, if the testing delays, maintenance time and downtimes exclusively due to feed characteristics were discounted, the system availability would be more than 70% for relatively trash-free soils.

A discussion of the major problems encountered, solutions adopted and lesson learned from these experiences is presented below.

o Kiln Problems due to Feed Characteristics

The nature of the feedstock presented several restrictions and caused several problems:

- The presence of combustibles providing more than 1000-1500 Btu/lb would cause kiln overheating (resulting in slagging) and thus limit throughput.

- The nature of the combustibles present in the feed caused slagging of the kiln walls with a lava-type refractory material that eventually built a dam restricting the flow of material through the kiln. The materials conducive to the slagging were plastic materials used to contain the contaminated dirt during transport to the site, the discarded clothing and material used during clean-up, such as rubber gloves, plastic suit material, boots, etc.

- The presence of excessive water in the contaminated soil caused the feed to become muddy and stick to the conveyor belt, weigh scale, and ram trough. The resulting buildup would periodically plug one or the other part of the feed system thus reducing overall feed rates. Occasionally, these blockages caused significant downtime.

  Although the feed system had trouble processing muddy soil, the kiln operated well with it. Due to the cooling effect of the water, the kiln was able to process increased quantities of high Btu material (plastics, paper, etc.) with reduced slagging. However, feed system problems cancelled much of this advantage.

TABLE 5 - CAUSES OF SYSTEM UNAVAILABILITY

Item	Unavailability (%)
Testing Delays	6.6
Kiln Pluggage	10.6
Feed Jamming	3.5
Mechanical	9.9
Electrical	2.3
WEP	4.6
Human Error	7.4
Maintenance	2.1
Total	47.0

TABLE 6 - UNAVAILABILITY DUE TO MECHANICAL FAILURES

Mechanical Items	Unavailability (%)
Venturi	6.3
Conveyor Belt	1.9
Kiln Bearing	0.5
Quench Tank Pump	0.5
Hydraulic Hose	0.4
Kiln Seal Breakage	0.3
Total	9.9

Some of the solutions used to overcome these problems were:

- Increasing the weight of combustibles fed per hour by adding non-combustibles such as soil and metals to absorb the heat generated.

- Excess water in the feed can be relieved by using small amounts of light weight absorbants such as vermiculite which eliminates the sticking of the muddy material while adding little throughput weight.

- The slagging of the kiln walls can be reduced by lowering the temperature within the kiln to near the low operating limits (1400-1450^{o}F) specified in the permits. The introduction of inert materials such as soil and metals (from cut up drums) causes the local temperatures of the incinerated material to be lowered and reduces the tendency of it to stick to the walls decreasing the rate of slag buildup.

The major lesson learned from these experiences is that during processing of large quantities of soil, the trash generated during the system operation should be processed simultaneously instead of being set aside for later processing. Soil containing a small fraction of plastic, trash, etc. is far easier to process than trash alone.

o Feed System Problems

The feed system for the MIS consists of four pieces of equipment: a slow-speed high-torque shredder, a belt conveyor, a batch-type weigh scale, and a hydraulic ram. Each piece of equipment can cause feed interruptions depending upon the feed material consistency and characteristics.

The shredder prepares most materials for feeding extremely well. However, wooden pallets and metal drum closure rings, may cause feed blockages when shredded in the present equipment. While most of the wooden pallet is broken into 2-inch wood chips, an occasional board will position itself to go through the shredder as a two inches wide by four feet long sliver. The same is true for the drum lid rings. The shredder sometimes drags the ring through, straightening it but not cutting it. In each case, plugging of the conveyor, weigh scale, or ram then follows. The only solution has been to manually remove the long slivers and put them back through the shredder. An active classifier below the shredder may provide a more suitable solution.

The conveyor has caused several problems. The "flexibelt" vertical sided belt is loaded from a hopper underneath the shredder. To keep the shredded material from spillingover the belt, a restricting dam is required to level the granular material as the belt exits the shredder hopper. While this

configuration works extremely well for granular material, it creates large blockages when materials such as shredded plastic, clothing, trash, metal, or mud is present in the feed. The removal of the restricting dam while feeding the troublesome material has alleviated the problem. A better long-term solution is the use of an active hopper dam and better classification of shredded material.

The conveyor belt was slit for 70 of its 85 feet by a metal shard from a shredded drum when the shard, stuck to the belt with mud, passed under the top-end belt wiper and lodged in the underside rollers. The top-end wiper was repositioned to provide a more positive wiping action.

The batch-type weigh scale provides an opportunity for materials to bridge and cause pluggage. Materials, which are not prepared well by the shredder, (wood slivers, shredded plastic and clothing, and any light fluffy substance) create a feeding problem. This problem can be alleviated by removing or covering internal chute projections with a smooth liner. In the long term, the use of a weigh belt feeder may be a better solution.

The ram provides an effective device to deliver feed to the kiln from the batching-type weigh scale. Several types of materials, however, have caused difficulties in ram operation. Long slivers of wood and/or metal have jammed and stopped the ram. Only classifying the feed, to remove oversize materials can eliminate this problem. Finely granulated material will bypass the ram head and collect on the backside thus preventing the ram from fully retracting. A small chain-plug conveyor was installed and timed to convey the bypassed material to the front side of the ram. This solution has worked quite well.

o <u>Kiln Bearing Failure</u>

The kiln is held in radial position by four rollers (two driven, two idlers). Each radial roller is supported by two pillow block-style bearings which are retained and locked on the roller shafts with Allen-style set screws. Gravity acts to move the tilted kiln in the down slope direction. The kiln axial position is maintained by a single thrust roller (made of soft steel) operating against gravity and the thrust ring.

The bearing failure occurred as follows: Over a long period of time the harder thrust ring had produced a groove (approximately 1/4" deep) in the axial roller. Several days after maintenance was performed on the pillow block bearing at the head (upper) end of the kiln, two bearing inner races held by the Allen set screws became loose and worked their way out of the bearing. This allowed the kiln rotating cylinder to drop 3/8". Because the thrust ring had worn a groove in the axial thrust roller, an extreme tilting force was applied to the thrust roller as a result of the movement. This in

turn caused a total failure of the two shaft bearings of the thrust roller. Since the failure was recognized quickly and kiln rotation was immediately stopped, no other physical damage occurred. The bearing failures were corrected by first ensuring that the Allen set screws on the pillow block bearings were properly fastened and then locked. Additionally, the thrust roller was rebuilt, the groove filled and the roller surface hardened to eliminate the future grooving.

o The SCC Exit Venturi and Diffuser

The SCC is completely lined with refractory, except for the exit venturi and diffuser, which are made of Inconel 625. After over 3,000 hours of operation, some of which was with highly chlorinated compounds, the exit venturi had completely disintegrated, and its support plate showed severe stress corrosion cracking. Based upon the presence of chlorine in conjunction with the high temperature (2200^{o}F) the material for the venturi and diffuser was changed to Haynes^{R} alloy 556. Further, a refractory throat was formed upstream of the metal throat. Finally, the water cooling nozzles used to wet the back side of the metal parts were changed to provide a more effective spray pattern.

o Spalling of Kiln Refractory Repair Patches

During a shutdown of more than one year, the kiln refractory was repaired with patches of refractory material. The startup procedure, as well as the safety interlocks, required that the kiln be rotated prior to lighting the kiln burners. Since the refractory patching material was of the non-hardening nature until it reached 600^{o}F, the cold rotation of the kiln caused the patched material to loosen and fall out before the burners were ignited and the refractory had cured. To prevent recurrence the start-up procedure has been changed as follows: The kiln does not need to be rotated until the outside (or shell) temperature begins to rise. Continuous rotation of the kiln is started when the internal temperature reaches approximately 700-900^{o}F. During the interim period, the kiln is rotated 1/4 turn every 10-15 minutes to minimize any thermal distortion of the shell.

o pH Control Problems

The scrubber system for the MIS utilize a caustic solution to neutralize the HCl gas formed and maintain the scrubber water pH in the 7 to 9.5 range. There are three areas in the MIS where the flue gas is scrubbed:

-Quench elbow and sump

-Lower WEP filler region

-Mass transfer (MX) scrubber

A 10-20% caustic solution is injected into the quench sump and into the recirculation water flow of the MX scrubber. The initial and largest percentage of the neutralization occurs in the quench elbow and sump. For that reason the majority of the caustic must be injected at this location. The pH is controlled with Beckman instrumentation operating in slip streams from the recirculation water loops. The injection of caustic directly into the quench system tank from a line controller by a solenoid valve located 25 feet upstream caused large swings in the pH (3-10.5) of the quench sump. The long injection line between the valve and the quench sump causes an initial delay in caustic injection after the valve is activated. The pH continues to decrease during this delay. After the valve is closed the line causes an uncontrolled trail-off of injection. The pH continues to rise during the trail-off. The swings could be controlled for any one condition of chlorine loading by altering injection timers. However, when chlorine loading changed sharply, the timing required manual changes. Also, under heavy loadings the swings were still excessive. Placing the caustic injection point into the recirculation system instead of directly into the tank greatly reduced the uncontrolled swings. However, after prolonged operation the quench nozzles began to plug with dried caustic. A final solution will require moving the control solenoid adjacent to the quench sump to prevent the control delays. Also, an enlargement of the quench sump would reduce this problem.

o <u>WEP Problems</u>

It was difficult to establish the required high voltage during initial start-up of the precipitator. The electrodes had to be accurately positioned within each box cell before voltage could be sustained without breakdown. After a hot cycle, the WEP again failed to hold high voltage because of electrode shorting. The electrodes were again adjusted and reinforcing angles were added to the rod suspension system. The unit performed normally for 20 days when all three circuit boards failed in the control panel catastrophically. No conclusive reason could be established for the failure, but metal chips from the initial cabinet assembly were thought to be the cause. After replacing the boards and turning off the fogging sprays, the unit has continued satisfactory operation. It has been necessary to perform a wash cycle daily or more often in heavy feed conditions to maintain high voltage. This wash cycle removes particulate buildup from the surfaces of box cells.

o <u>Human Error</u>

As mentioned earlier, during one of the trial burn tests the kiln bearings had failed. The failure caused the test to be incomplete. The system was manually shutdown. This action stopped the waste feed, and turned off the kiln and SCC burners and the induced draft (ID) fan. The ID fan was

quickly restarted but, the SCC burners were not turned on. This caused the generation of furans from partial combustion of PCB remaining in the kiln. Consequently, the process water system was contaminated with these furans.

The contamination of the process water system was not discovered until a trial burn test was completed the next day. The complete process water system was later decontaminated using carbon filters. A risk analysis was performed on this incident in accordance with the US EPA guidelines (7). From this risk analysis, it was determined that this incident did not result in any significant impact on the surrounding population.

The primary lesson learned from this experience is that should the kiln rotation be stopped, the SCC burners must not be turned off. Operators have been instructed to ensure that SCC burners are kept on if at all possible.

CONCLUSIONS

Based on the demonstrated test results, it is concluded that the modifications made to the MIS have been successful. The capacity of the MIS has been increased by more than a factor of 2. The MIS presently is permitted to burn dioxin-contaminated materials at 4000 lb/hr. The problem of particulate accumulation in the SCC, requiring its frequent clean-up, has been completely alleviated. The cyclone and the WEP have demonstrated excellent performance in solving that problem.

Successful operations with very low density vermiculite has been demonstrated. Tests with mixtures of brominated sludge, soil and sodium sulfate have also been successful.

The on-stream factor of the MIS has improved considerably since the system has been modified. For a relatively trash-free soil, the MIS on-stream factor would be more than 70%.

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